DESIGN OPTIMIZATION OF SPACE STRUCTURES

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This project investigates the topology-shape-size optimization of space structures through Kikuchi's homogenization method.

The method starts from a "design domain block," which is a region of space into which the structure is to materialize. This domain is initially filled with a finite element mesh, typically regular. Force and displacement boundary conditions corresponding to applied loads and supports are applied at specific points in the domain.

An optimal structure is to be "carved out" of the design under two conditions: (1) a cost function is to be minimized, and (2) equality or inequality constraints are to be satisfied. The "carving" process is accomplished by letting microstructure holes develop and grow in elements during the optimization process. These holes have a rectangular shape in two dimensions and a cubical shape in three dimensions, and may also rotate with respect to the reference axes. The properties of the perforated element are obtained through an homogenization procedure. Once a hole reaches the volume of the element, that element effectively disappears.

The project has two phases. In the first phase the method has been implemented as the combination of two computer programs: a finite element module, and an optimization driver. In the second part we plan to focus on the application of this technique to planetary structures.

The finite element part of the method has been programmed for the two-dimensional case using four-node quadrilateral elements to cover the design domain. An element homogenization technique different from that of Kikuchi and coworkers was implemented. The optimization driver is based on an augmented Lagrangian optimizer, with the volume constraint treated as a Courant penalty function. The optimizer has to be especially tuned to this type of optimization because the number of design variables can reach into the thousands. The driver is presently under development.

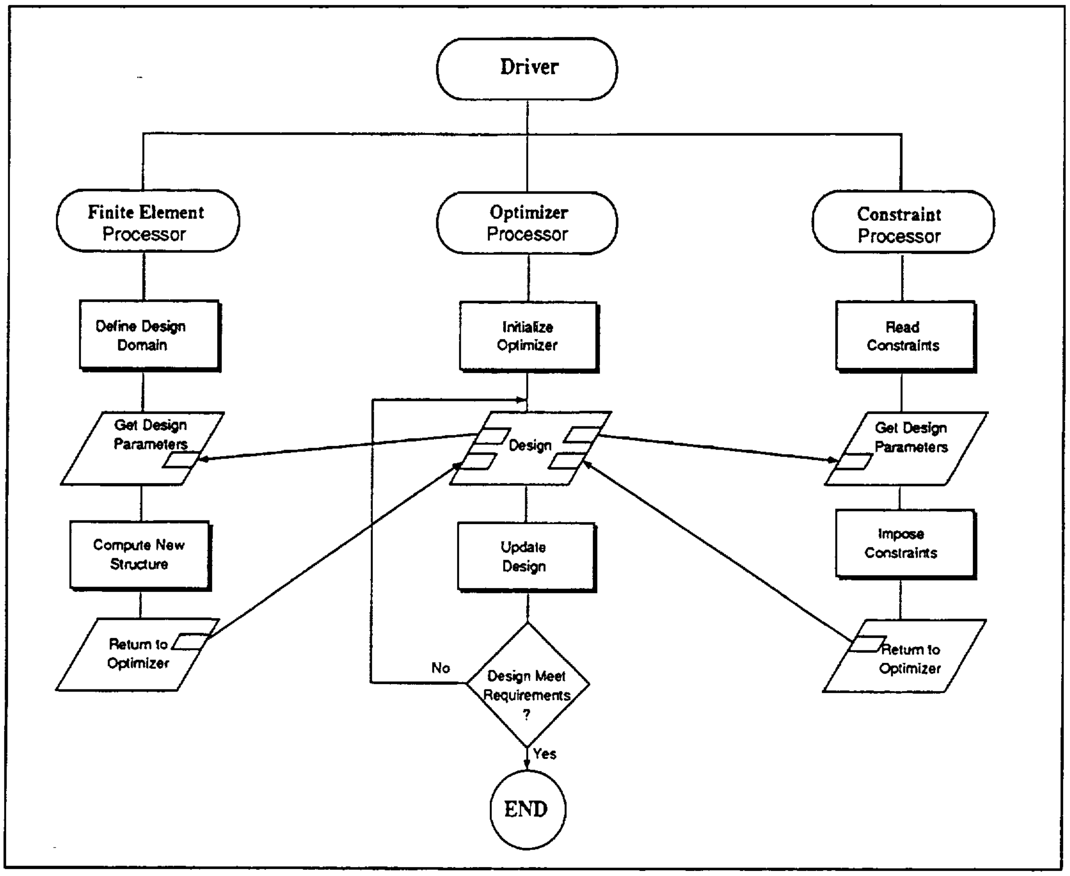
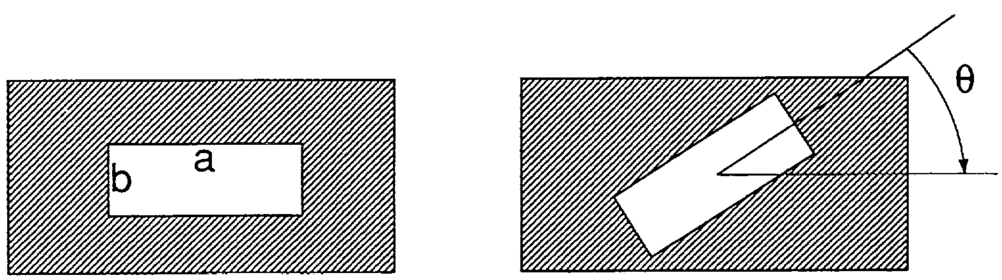


Fig 13.1 Schematics of the optimization program



In two dimensions: a, b, θ in each element (3)

In three dimensions: a, b, c, θ_1, θ_2, θ_3 in each element (6)

100×100 2D mesh: 30,000 Design Variables

$30 \times 30 \times 30$ 3D mesh: 162,000 Design Variables

▹ Taking Advantage of Design-Variable Locality Essential

Fgi 13.2 Element-level design variables: micro-hole dimensions

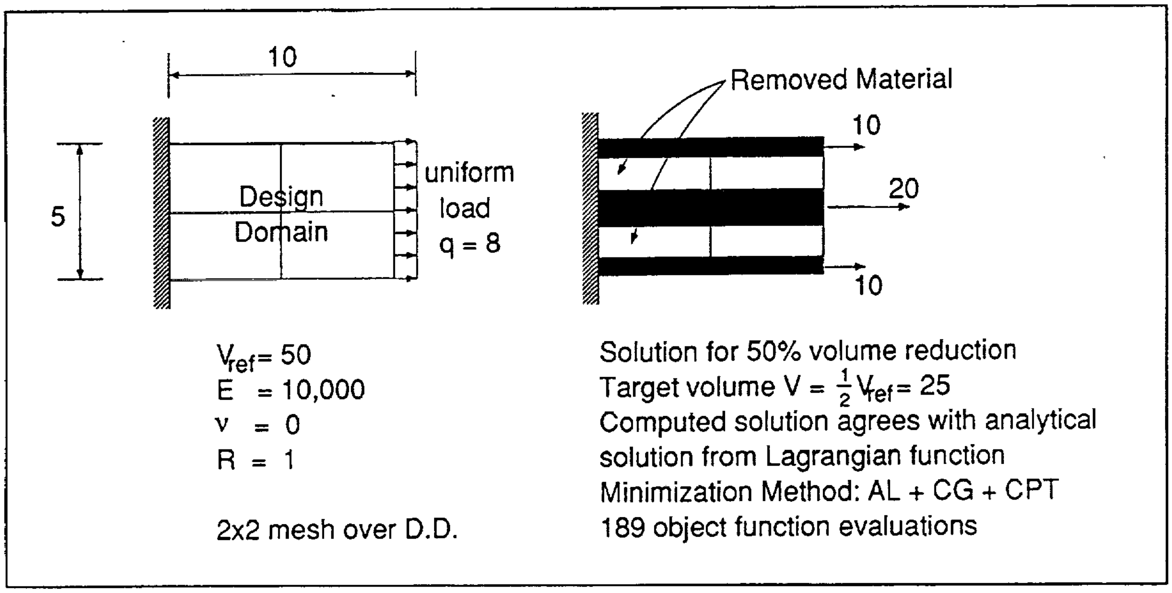


Fig 13.3 First successful solution of the validation problem

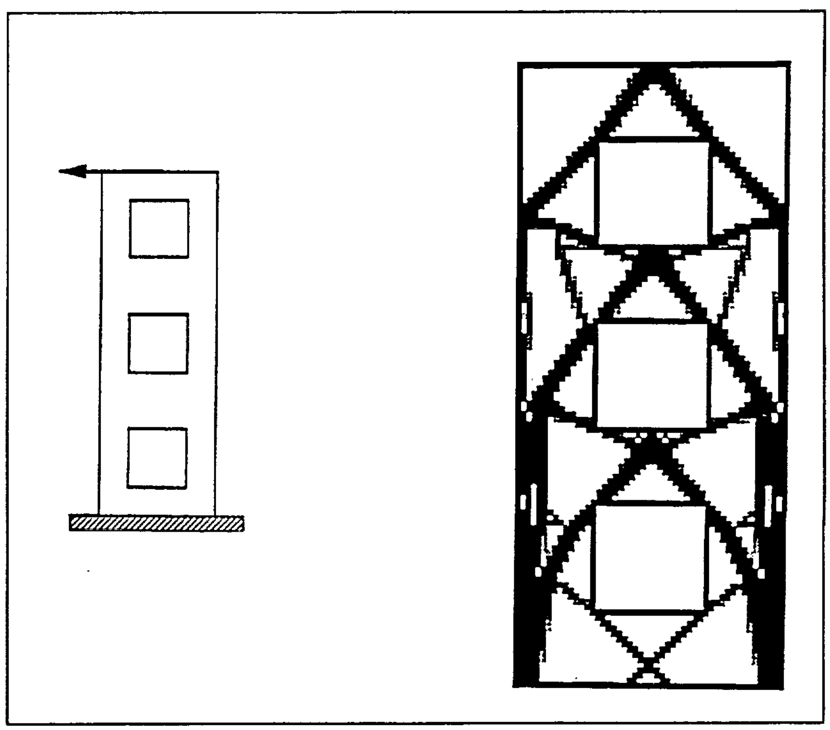


Fig 13.4 Example of predetermined holes which may be contained in the design domain